

I have also compiled a table in which is given what might be termed safe practical moduli of rupture for six of the principal hardwoods of the group. This I have made up from the different series of experiments, giving them values in accordance with their comprehensiveness and completeness, and then making certain deductions to ensure being upon the safe side. I have confidence that the results present fair average values for the transverse strength of the timbers named ; that they err, if at all, in being below the mark ; and that they are sufficiently sure data for all calculations for purposes of construction.

Timber.				Moduli of Rupture.	
1. Ironbark	16,000 hs.
2. Bluegum	11,000
3. Yellow box	10,000
4. Spotted gum	10,000
5. Stringy-bark	9,000
6. Redgum	8,000

Tamworth, N.S.W., October 31st, 1881.

ART. VI.—*Floods on the River Barwon.*

BY W. C. KERNOT, M.A., C.E.

[Read 8th June, 1882.]

HAVING been prevented by circumstances of a very painful and urgent nature from taking part in the discussion upon Mr. W. W. Culcheth's paper upon the above subject, I venture at this comparatively late period to submit my views upon a question which all will admit to possess the highest practical importance.

The due proportioning of the waterway of bridges is a question of vital moment to the railway, road, or hydraulic engineer. If the waterways are made needlessly large, the waste of money may be most serious ; if they are unduly

small, as I maintain them to have been at Geelong, disasters of unparalleled magnitude may be the result. The problem that has been presented at Geelong will recur from time to time as our railways and roads extend, and the damage to property, in the event of insufficient waterway being provided, will increase indefinitely as population becomes denser, and the margins of our rivers become fringed with mills and factories and dwellings. Hence it is of the highest importance that a proper scientific system of dealing with the question should be adopted generally by the profession.

The enquiry before us is this, was the department's design for the Barwon Bridge right or wrong, sufficient or insufficient, and was the flooding of the Woollen Mills independent or not of the presence of the railway works? The former view was strenuously maintained by the Government witnesses at the trial, including amongst their number the gentleman at present occupying the honourable and important position of Engineer in Chief of Victorian Railways. The latter is Mr. Culcheth's opinion and my own.

Without going into the arithmetical details, I would say at the outset, that my own calculations, made prior to the publication of Mr. Culcheth's results, agree very closely with his conclusions as to the discharge of the river, and the extent to which the water rose in the mills above what would have been its level had the railway works not been in existence. This latter amount is given by him as 3.70 feet, and by me as 3.50 feet.

In order to verify this result as far as possible by direct experiment, a model was made representing, to scale, the bed and valley of the river for a distance of about a mile and a half above and below the railway works, and corresponding in this respect with Mr. Culcheth's lithographed section. Water was caused to flow over this model until a flood was produced, corresponding with the actual flood marks of 1880. The railway works made in a separate piece were then removed, and the water fell through a height of 4 feet, according to the scale of the model. On replacing the wooden representative of the railway bank, the water rose again to its original position. The experiment was repeated a considerable number of times with identical results, and taken in conjunction with the calculations, establishes most conclusively the truth of the proposition, that had the railway bank not been in existence, the water in the factories would have been from three to four feet lower than it

actually was. An inspection of the water as it flowed over the model threw important light on some points of difficulty. For example, the comparatively high water level at Haworth's Tannery, which is on the downstream side of the bridge, had been a source of a little perplexity, but on the model the true constriction and most rapid fall of the water was seen to be *not under the bridge itself, but on a line drawn from the south end of the bridge to the south-west angle of the tannery*. The width of the stream at this point is *less than half* the length of the bridge. Another point of interest that presented itself was the marked effect of the piles of the bridge in breaking up the stream and retarding the flow.

I propose to criticise in detail the departmental mode of dealing with the problem, and also various statements made at the trial by the departmental witnesses, and which I conceive to be erroneous and unscientific.

The first noteworthy point is the serious error that occurred in determining the high flood level of 1852. This was at the time of constructing the works fixed at 16.53 feet above datum, but on the trial commencing, the old value was abandoned and 19.85 substituted. The ease with which evidence was obtained for this latter value, leads to the conclusion that but little care was taken at the earlier date to obtain a reliable height. Further, it is to be noted that the flood mark of 1852 was well known at Collins' Mill, $1\frac{1}{2}$ miles higher up the river, and that a calculation based upon this and the 16.53 flood mark, leads to a discharge of enormous magnitude, many times greater than the part of the valley lower down could possibly carry away without the water rising to a level far higher than 16.53. In view of the accessible and highly reliable flood mark at Collins' Mill, the 16.53 flood level is physically impossible. Had the above-mentioned calculation been made when the works were being first laid out, a most serious error would have been detected.

Next it was reiterated that, however the case might be with a 19.85 feet flood, that the railway works provided ample waterway for a 16.53 feet one. Now I would most emphatically endorse Mr. Culcheth's opinion, that it is impossible to determine waterway by reference to high flood mark alone. It is absolutely necessary that discharge should be also determined, and this it seems was never ascertained by the officers of the department. Calculating the discharge

from the Collins' Mill flood mark and the 16.53 level at the railway, the result is found to be no less than 180,000 cubic feet per second. But the openings provided at the railway have an effective area up to a level of 16.53 of less than 5000 square feet. Dividing 180,000 by 5000 we find that to discharge the flood the water must pass through the openings at the incredible velocity of *36 feet per second*, or more than 20 miles per hour. To produce this velocity a heading up of *20 feet in height* would be needed. Had the railway engineers made this simple calculation when designing the bridge, one of two results must have happened—either they would have enlarged the waterway at least four-fold, or they would have rejected the data upon which the computation was based, and sought further information.

If we abandon the Collins' Mill flood mark, and take the 16.53 flood level at the railway as the only datum, it is not possible to make any calculation at all, as no velocity can be ascertained. However, an experiment upon the model before-mentioned showed that when the water stood at 16.53, at the Breakwater it was about level with the flow of the Victoria Mill, 17.30, and that if the railway bank were then inserted the water rose to 20 at the mill, flooding it to a depth of 2.70 feet. In view of this experiment and the preceding calculation, I must dissent most emphatically from the statement of the railway engineers, that the bridge was correctly designed in view of the data supplied by the field officer.

In the evidence given on the side of the department, it was repeatedly asserted that the railway works gave about double the waterway of the large road bridge in the vicinity, and the waterway was stated to be 735 and 390 lineal feet in the two cases respectively. Upon this comparison the opinion of the railway engineers as to the sufficiency of their works appears to have been based. But the comparison is altogether erroneous. In the first place it is tacitly assumed that the road bridge was large enough, whereas experience proves that it is not, a portion of the flood escaping over a low part of the approaches. Next the 735 feet includes the Waurn Ponds Creek Bridge 135 feet long, and as this creek is a totally distinct stream from the Barwon, it is manifestly quite unfair to include it. Thirdly, the bridge over the main stream, though really 600 feet long, is placed in so peculiar a position as to leave only 290 feet between its south end and Haworth's Tannery, through which the whole

stream has to pass, and this 290 feet is so surrounded by obstructions in the way of piles, iron rods, walings, braces, stanchions, and chains, also a great bed of reeds, and several dead trees, that I fail to see that it is equal in discharging power to more than one half of the clear unobstructed opening of 390 feet at the road bridge. Thus the railway bridge *instead of double, affords only half the effective waterway of the road bridge*, which itself has proved not quite large enough. In the experiments with the model, it was observed that the heading up of the water at the road bridge was always less than half that which occurred at the railway, and that in this latter case the great fall in the surface of the water took place, not under the bridge, but between the south end of the bridge and the south-west corner of Haworth's Tannery, and just below the point where the true constriction exists.

In conclusion, I feel bound to raise my most earnest and emphatic protest against the way in which the gentlemen on the defence set aside scientific laws and formulæ as "mere theory," and insisted on practice being the only guide. Now, Sir, what is this theory but the practical experience of the best and wisest men that have ever given their attention to the subject, systematised, verified, and adapted to cases of ordinary professional work? And what is practice but simply one's own way of doing one's work, differing in every individual case, which may be right or wrong, scientific or crude, economical or extravagant, according to the mental constitution, and amount of education possessed by the engineer? The popular idea that science is mere theory, and unreliable when brought to the test—while practice, ignorant, inconsistent, and unintelligible, as it too often is, is the only guide to be followed, is a delusion leading to the most deplorable results.
